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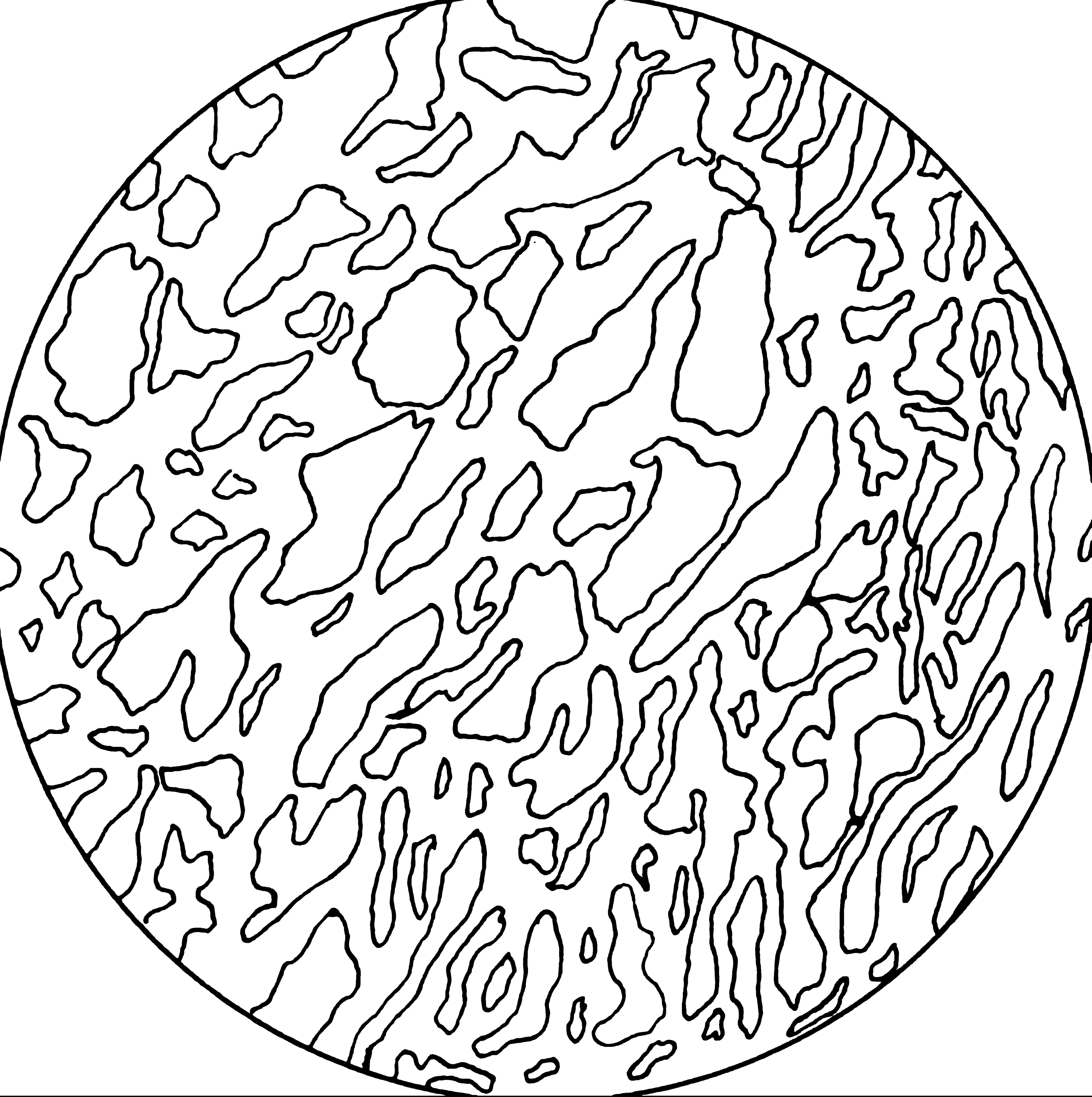

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MICROSCOPIC INVESTIGATION OF ALLOYS

by

CLARENCE EUGENE ABBOTT

A Thesis Submitted for the Degree of

BACHELOR OF SCIENCE

in

M. ENGINEERING

UNIVERSITY OF WISCONSIN

1901

MICROSCOPIC INVESTIGATION OF ALLOYS.

INTRODUCTION.

The object of this thesis is to carry to some further extent the work of Messrs. Harvey and McArthur upon metallic alloys, as submitted in their thesis entitled "Microscopical Analysis of Steel and Alloys as a Commercial Test." Camera luceda drawings have been made together with micro-photographs. The luceda drawings of the specimens seem to show to a much better degree the irregular shape and approximate size of the crystalites. They also enable one to make a comparison, by means of the planimeter, of the area of the metals exposed upon a cross-section and the percent of metal in the alloy.

It is known that the area of a metal exposed in a cross-section is practically proportionate to the percent of that metal in the alloy. This is not mathematically true unless the areas are of infinite number and of equal distribution. If the areas can be found to bear a certain relation to the percent of metal in an alloy, then the volumes must also bear a relation. Binary compounds were dealt with mainly because their structure is comparatively simple and thus much easier to study.

The specimens were weighed in one hundred gramme lots. They were melted in a coke draft furnace and when

practicable in a gasoline blast. Oxidation seemed to be less in a gasoline blast than in the coke draft furnace. Hessian crucibles were used in which to melt the alloys. The metals having a lower melting point were first melted in the crucible, then those having a higher melting point were added. This method cut down time upon some of the alloys, as the metals would melt much faster and oxidize less when put in a mixture already molten. To prevent oxidation powdered charcoal and argol were used as a covering. These substances always rose to the surface as fluxs and did not mix with the alloys in any way. After sufficient heat was secured to melt the metals, the crucible was removed from the furnace and whirled and shaken well and then poured.

The mixing was found to be of the utmost importance as metals having a lower specific gravity would rise to the top and be poured first, thus making a very poor alloy. It is quite necessary to mix well so as to secure a good mechanical and, if possible, a chemical mixture. The molten metal was poured into ordinary molding sand moulds and allowed to cool gradually in the open air. Cross sections were made by cutting vertically across the specimen with a hack saw. Generally three specimens

were secured from each pouring and these were each cut twice with the hack saw. In some cases side sections were made, but these showed practically the same structure as the cross section.

It was found that the best manner in which to secure a smooth flat surface was to take the specimen between the thumb and forefinger and draw it over the surface of a smooth cut file. In some cases ordinary vice filing was resorted to. After having secured an approximately level surface, the specimen was ground upon a lead mat.

Fine emery powder was used as a frictional agent to remove the file marks. In cases where the alloys were very soft (those containing much lead or tin) a great amount of trouble was met with in securing a surface free from a mat or skin of the softer metal. This trouble was obliterated by scraping with an ordinary steel hand scraper. The scraper cut off the ends of the crystallites and injured them very little, if any.

After treating in this manner, the specimens were washed in water and dried. They were then polished upon chamois skin laps with jeweler's rouge. It is very important that very little pressure be applied to a specimen when polishing or grinding it down, for the reason

that the softer parts will be torn out, and the harder parts rounded so as not to give their true shape and outline. The best results were obtained in polishing by moving the specimen in the path of a figure 8. After polishing they were again washed in water, then in alcohol, and dried with a piece of soft linen.

Various reagents have been used for etching purposes, but those best suited for the alloys used in this experimental work were found to be nitric and hydrochloric acid. In the case of nitric acid, the specimens were dipped, then quickly washed in water. The action of the reagent seemed to take place more quickly as soon as the specimen touched water. In the case of hydrochloric acid some little time was required in almost every case. By using these acids, some of the metals were etched out, while others were acted upon but very slightly, if at all.

Hydrochloric acid dissolves tin and covers lead with a white layer of lead chloride. Nitric acid dissolves lead and covers tin with a white layer of meta-stannic acid. After etching, the specimens were again washed in water, then in alcohol, and dried with a soft chamois skin. Artificial reflected light, intensified by a bullseye condensor was used to bring out the structure of the etched specimens.

DESCRIPTION OF PLATES.

Plate I.

Specimen 1. Alloy of tin and antimony. Sn. 80, Sb. 20. Magnified 110 diameters. Cubes are of SnSb. The matrix is an eutectic alloy of Sn + SnSb and is quite uniform in structure.

Plate II.

Specimen 2. Alloy of tin and antimony. Sn. 70, Sb. 30. Magnified 110 diameters. Cubes are of SnSb. The matrix, solidified between the cubes, is of Sn + SnSb.

Plate III.

Specimen 3. Alloy of tin and antimony. Sn. 60, Sb. 40. Magnified 110 diameters. Larger crystallites are a compound of SnSb. while the space separating them is the eutectic alloy Sn + SnSb.

Plate IV.

Specimen 4. Alloy of tin and antimony. Sn. 57$\frac{1}{2}$, Sb. 42$\frac{1}{2}$. Magnified 110 diameters. The main crystallites are composed of SnSb. Scattered through them are tiny crystals of pure Sn. The dark portion between these larger crystals is an eutectic alloy of Sn + SnSb.

Plate V.

Specimen 5. Alloy of tin and antimony. Sn. 55, Sb. 45. Magnified 110 diameters. The long crystallites, as also the smaller ones, are a compound of SnSb. The matrix is Sn + SnSb.

Plate VI.

Specimen 6. Alloy of tin and antimony. Sn. $52\frac{1}{2}$, Sb. $47\frac{1}{2}$. Magnified 110 diameters. Long crystallites, as well as the smaller ones, are of SnSb., while the matrix is of Sn + SnSb.

Plate VII.

Specimen 7. Alloy of tin and antimony. Sn. 50, Sb. 50. Magnified 110 diameters. Smaller crystals are of pure tin. The large crystallites are of SnSb. while the matrix is of Sn + SnSb. There appears a secondary crystallization around the Sb. crystals upon prolonged etching.

Plate VIII.

Specimen 8. Alloy of antimony and lead. Sb. 10, Pb. 90. Magnified 160 diameters. The small crystals are of almost pure antimony while the mixture in which they are imbedded is of SbPb. with Pb. more in evidence.

The Sb. goes into the eutectic alloy of $SbPb_4$, according to Charpy.

Plate IX.

Specimen 9. Alloy of antimony and lead. Sb. 20, Pb. 80. Magnified 110 diameters. Cubes and irregular crystals are of Sb. while the matrix is an eutectic mixture of $SbPb_4$. It is sometimes filled with tiny blow holes resulting from the etching out of the Pb.

Plate X.

Specimen 10. Alloy of antimony and lead. Sb. 30, Pb. 70. Magnified 110 diameters. Crystals of irregular shape and also the cubes are of Sb; they rest in a matrix of $SbPb_4$.

Plate XI.

Specimen 11. Alloy of antimony and lead. Sb. 40, Pb. 60. Magnified 110 diameters. Irregular crystals are of Sb. imbedded in a eutectic alloy of $SbPb_4$.

Plate XII.

Specimen 12. Alloy of tin and lead. Sn. 90, Pb. 10. Magnified 160 diameters. Crystallites are of Sn. SnPb. lies between these crystallites. Structure

is not uniform. The crystallites are nearly all Sn. as they appear white, and have not been etched by HNO_3.

Plate XIII.

Specimen 13. Alloy of tin and lead. Sn. 80, Pn. 20. Magnified 160 diameters. Small crystallites are the eutectic alloy SnPb. Matrix is nearly all Sn. and very uniform in structure with some Pb. which has been oxidized out.

Plate XIV.

Specimen 14. Alloy of tin and lead. Sn. 60, Pb. 40. Magnified 160 diameters. Crystallites are of Sn. imbedded in a uniform mixture of Sn. and Pb.

Plate XV.

Specimen 15. Alloy of zinc and tin. Zn. 90, Sn. 10. Magnified 110 diameters. Crystallites are of zinc. The dark portions are of the eutectic SnZn. There are crystallites of the eutectic alloy too small to be included in this drawing.

Plate XVI.

Specimen 16. Alloy of antimony, aluminum, and lead. Sb. 40, Al. 45, Pb. 15. Magnified 110 diameters. Large

crystals are of Sb., while between them lie tiny crystallites of Al. The eutectic alloy of $SbPb_4$. occupies the space between the crystallites of the two metals.

Plate XVII.

Specimen 17. Alloy of aluminum and lead. Al. 5, Pb. 95. Magnified 110 diameters. Small crystallites are of aluminum. The matrix is of Pb. These two metals do not form a good mechanical mixture because of the great difference in specific gravity.

Plate XVIII.

Specimen 18. Alloy of tin, antimony, and lead. Sn. 40, Sb. 35, Pb. 25. Magnified 150 diameters. Large crystals are of an eutectic alloy of SnSb. The matrix is a mixture of the three metals. The eutectic occupies tiny spaces near the crystallites of SnSb.

Plate XIX.

Print 1. Alloy of tin and antimony. Sn. $52\frac{1}{2}$, Sb. $47\frac{1}{2}$. Crystallites are of (SnSb) tin and antimony. Matrix is of Sn + SnSb. The eutectic alloy Sn + SnSb occupies portions of (SnSb) tin and antimony crystals in places.

Plate XX.

Print 2. Alloy of lead and antimony. Pb. 50, Sb. 50. White crystallites and the irregular, faintly outlined crystallites are of antimony. The eutectic ($SbPb_4$) is uniform in structure and constitutes the matrix.

Plate XXI.

Print 3. Alloy of lead and antimony. Pb. 60, Sb. 40. Crystallites are of antimony. They assume a cubical shape and rest in an eutectuc alloy of ($SbPb_4$) antimony and lead.

Plate XXII.

Print 4. Alloy of tin and lead. Sn. 90, Pb. 10. The large white crystallites are of nearly pure tin. The eutectic alloy of ($SnPb$) tin and lead lies between them and has been etched out by the reagent. Extremely dark spots are nearly pure lead.

Plate XXIII.

Print 5. Alloy of tin and lead. Sn. 70, Pb. 30. Crystallites in this specimen are of tin. The matrix is a mixture of tin and lead with more of the lead.

Plate XXIV.

Print 6. Alloy of tin and lead. Sn. 60, Pb. 40. Crystallites are of tin. They rest in a uniform mixture of tin and lead. Lead is more in evidence in the matrix.

Plate XXV.

Print 7. Alloy of tin and lead. Sn. 50, Pb. 50. Irregular whitish crystallites are tin.(SnPb) lead and tin form the greater portion of the matrix.

Plate XXVI.

Print 8. Alloy of zinc and tin. Zn. 90, Sn. 10. Crystallites are of zinc. The dark portions are of the eutectic (SnZn) tin and zinc.

Plate XXVII.

Print 9. Alloy of zinc and tin. Zn. 70, Sn. 30. Dark crystallites of zinc. The matrix is an eutectic mixture of zinc and tin.

Plate XXVIII.

Print 10. Alloy of zinc and tin. Zn. 50, Sn. 50. Irregularly shaped crystallites are of zinc. The eutectic mixture (ZnSn) zinc and lead occupies the lighter colored portions of the specimen.

Plate XXIX.

Print 11. Alloy of tin, antimony, and lead. Sn. 40, Sb. 35, Pb. 25. Large crystallites are of an eutectic alloy of (SnSb) tin and antimony. The matrix is a mixture of the three metals. The eutectic of ($SnPb_4$) lead and antimony occupies portions near the crystallites of SnSb.

Plate XXX.

Print 12. Alloy of antimony, aluminum, and lead. Sb. 40, Al. 45, Pb. 15. Large crystallites are of antimony, around them lie small crystallites of aluminum. The eutectic alloy is vlack and is a compound of ($SbPb_4$). Other eutectic alloys are probably present also.

Plate XXXI.

Print 13. Alloy of lead, zinc, and antimony. Pb. 80, Zn. 10, Sb. 10. This is a rather uniform structured alloy. Dark crystallites are lead. The whitish portion is ($SbPb_4$) antimony and lead. There are probably other eutectic mixtures in this alloy.

Plate XXXII.

Print 14. Alloy of zinc and lead. Zn. 90, Pb. 10.

Dark crystallites are of lead. White portion in which lead is imbedded is an eutectic alloy of (ZnPb) zinc and lead.

Plate XXXIII.

Print 15. This specimen is a Babbitt metal with composition unknown.

CONCLUSION.

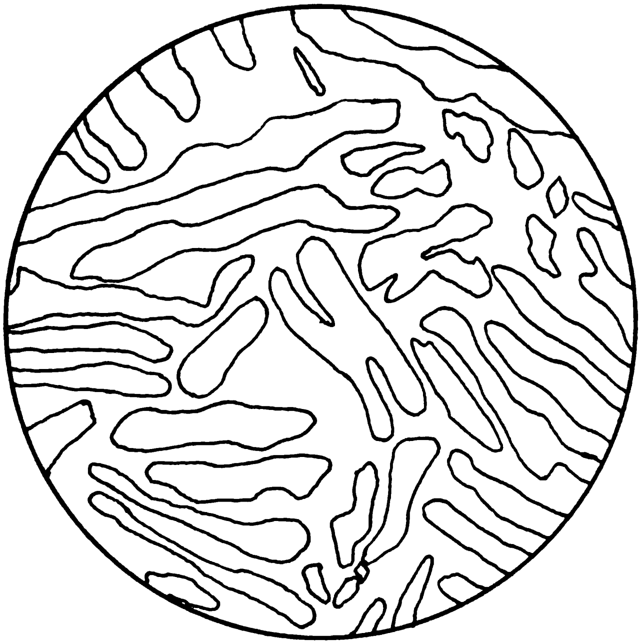
Antimony and tin compounds were the first dealt with. In these alloys, as probably in all binary alloys, there seem to be generally two principal constituents; the first is composed of one of the metals or of a definite compound, while the other is a mixture which is generally eutectic and made up of a compound of the two metals. The first compound rests in a matrix of the second. The proportion of crystals of the single metal varies with the composition of the alloy.

With less than thirty-five percent of antimony it was found that the crystallites always assumed a cubical shape, which were in place, quite regular in outline. With an increase of antimony to forty percent, the structure became decidedly different in appearance. The cubical crystallites disappeared and in place came the large, irregular crystallites of the antimony. These, when examined further, were found to be composed of aggregates of tiny cubical shaped crystallites. Beyond forty-two and one-half percent of antimony, the crystallites assumed an elongated structure and also were composed of the tiny cubical crystallites of secondary structure.

Upon etching a sufficient length of time, a secondary crystallization of tiny antimony crystals appeared surrounding the larger antimony crystallites.

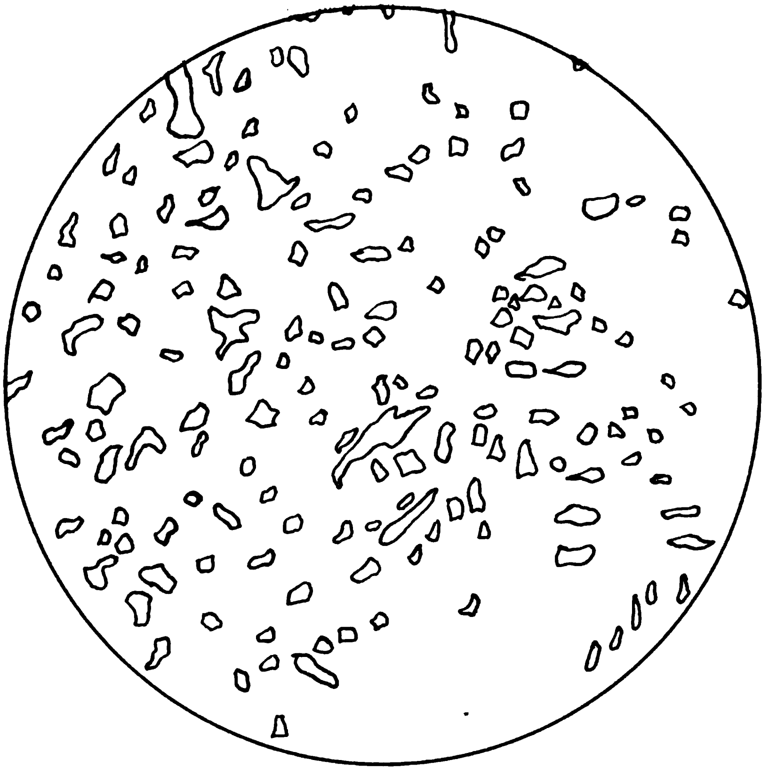
The antimony and lead alloys show the antimony crystalized in a manner very similar to those of the antimony and tin alloys. The crystallites were irregular cubical forms. Beyond thirty percent of antimony, these also appeared to crystallize in long irregular shaped crystallites which were undoubtedly composed of the tiny cubical forms. In these alloys the two metals form a eutectic mixture of antimony and lead ($SbPb_4$) according to Charpy. This eutectic generally constitutes the matrix of the specimens.

The tin and lead alloys are quite uniform for percentages of lead alove thirty-five percent, but where more tin is used it crystallizes out in long crystallites. The lead and the tin appear in alternate laminae. With more than thirty percent of lead the structure is quite uniform but with fifty percent they are especially so. These two metals form a eutectic mixture ($SnPb$). In the alloys containing more than two metals, several eutectic compounds form, probably four or five in some cases.



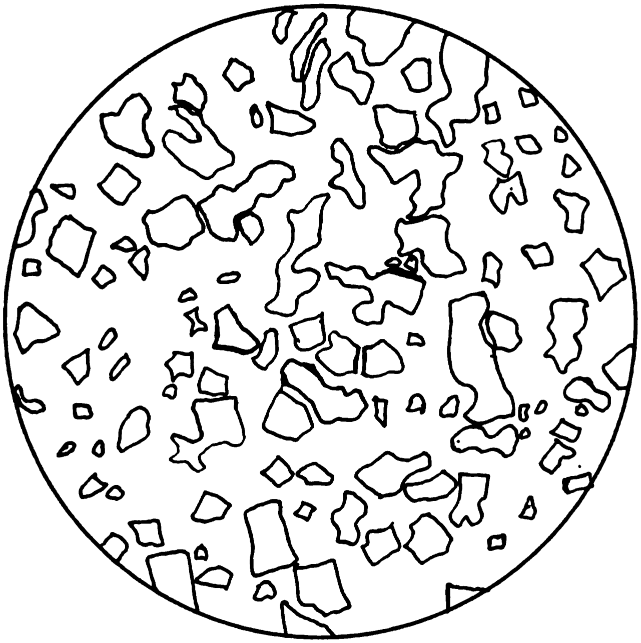
Drawing of Tin and Antimony Alloy. Sn. 50 percent. Sb. 50 percent.

Magnified 110 diameters.



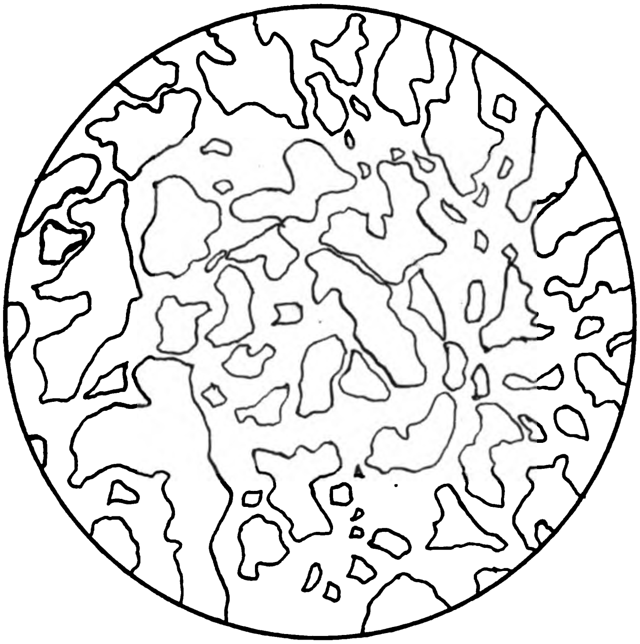
Drawing of Antimony and Lead Alloy. Sb. 10 percent. Pb. 90 percent.

Magnified 160 diameters.



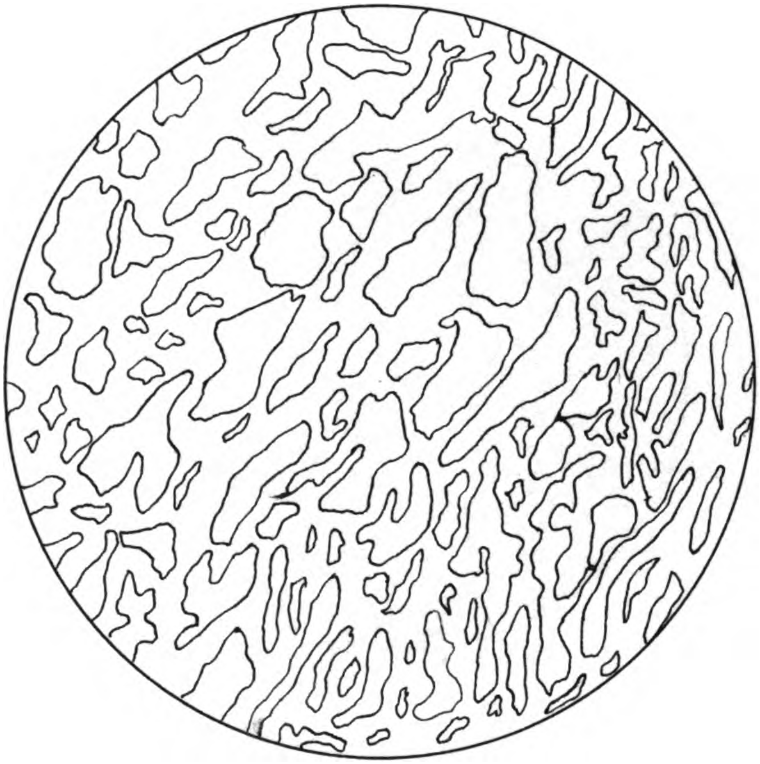
Drawing of Antimony and Lead Alloy. Sb. 20 percent. Pb. 80 percent.

Magnified 110 diameters.



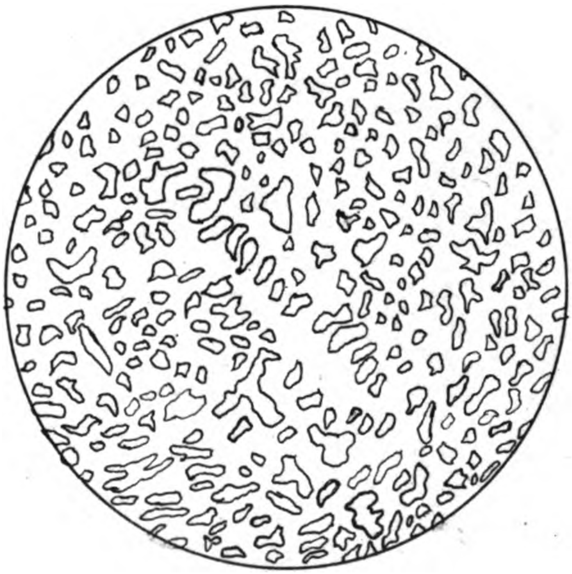
Drawing of Antimony and Lead Alloy. Sb. 40 percent. Pb. 60 percent.

Magnified 110 diameters.



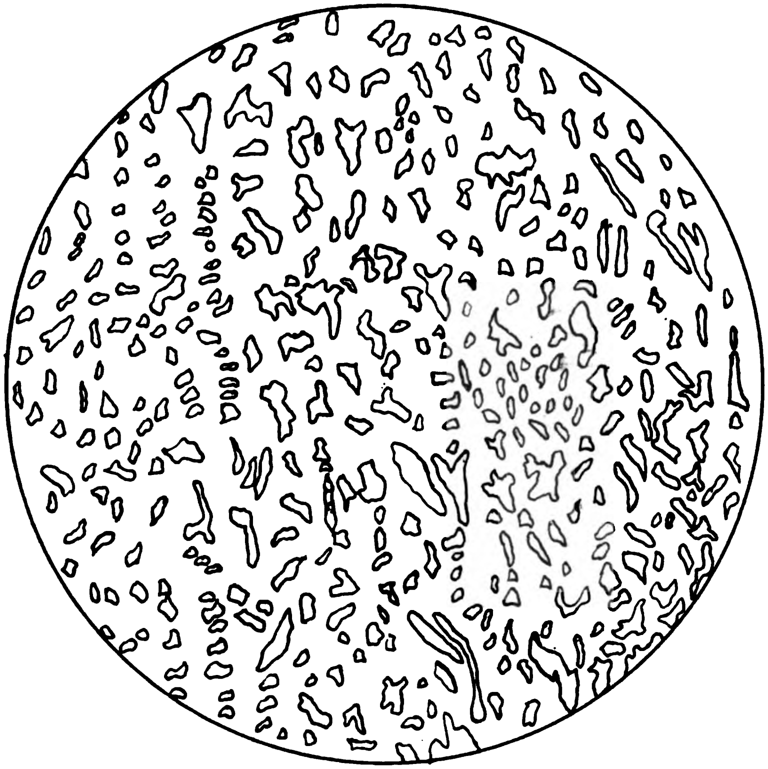
Drawing of Tin and Lead Alloy. Sn. 90 percent. Pb. 10 percent.

Magnified 160 diameters.



Drawing of Tin and Lead Alloy. Sn. 80 percent. Pb. 20 percent.

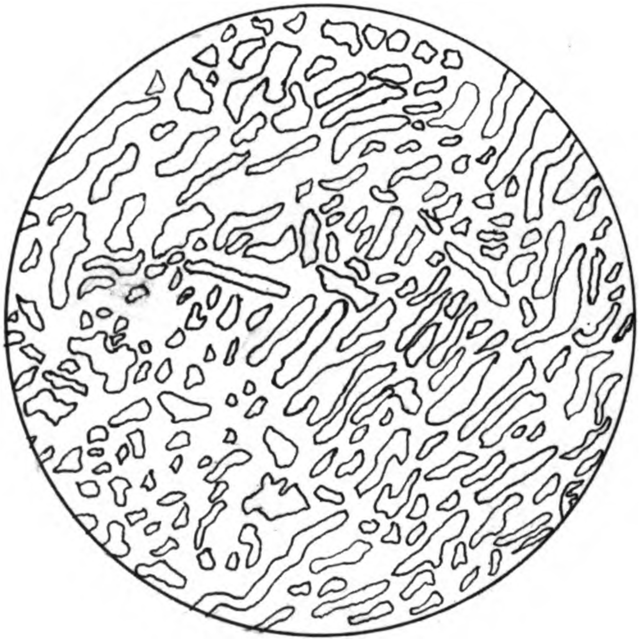
Magnified 160 diameters.



Drawing of Tin and Lead Alloy. Sn 60 percent. Pb. 40 percent.

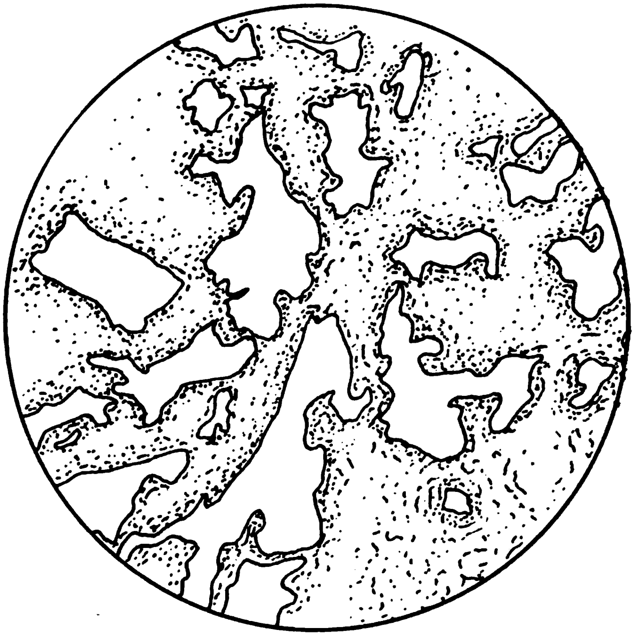
Magnified 160 diameters.

PLATE XV.



Drawing of Zinc and Tin Alloy. Zn. 90 percent. Sn. 10 percent.

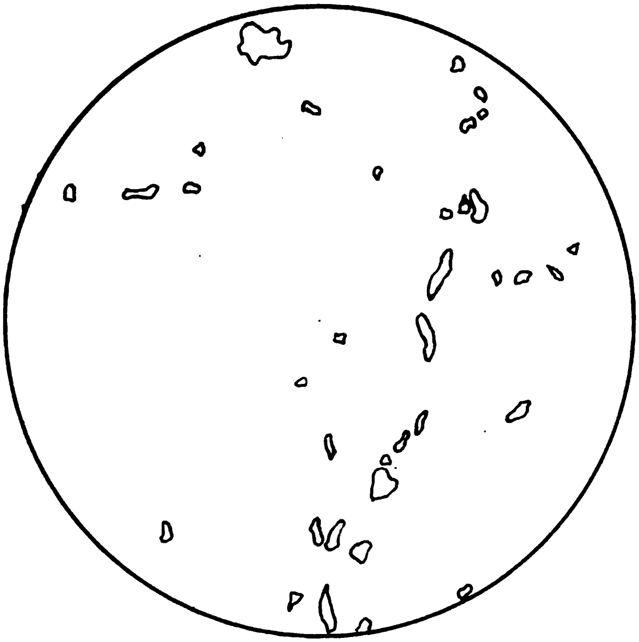
Magnified 110 diameters.



Drawing of Antimony, Aluminum and Lead Alloy.

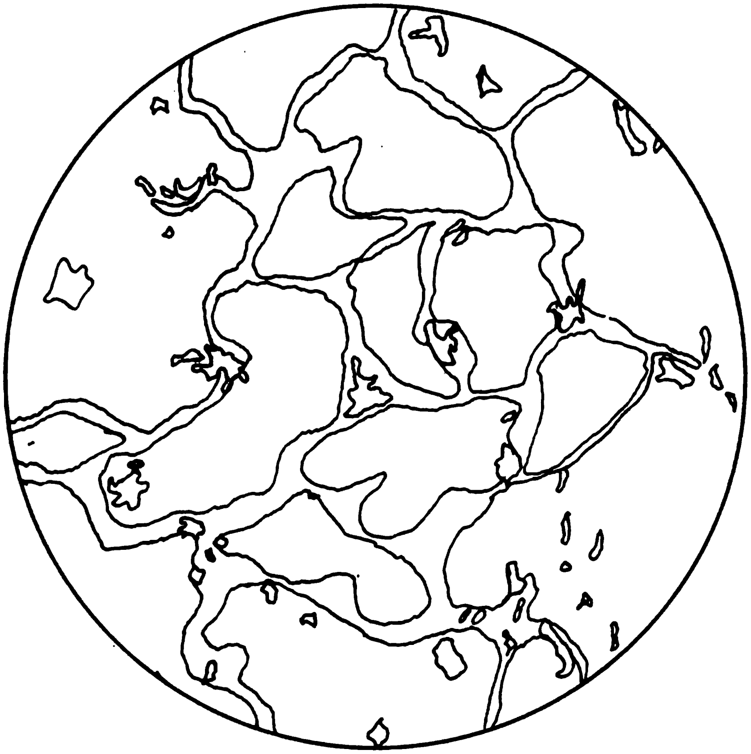
Sb. 40 percent. Al. 45 percent. Pb. 15 percent.

Magnified 110 diameters.



Drawing of Aluminum and Lead Alloy. Al. 5 percent. Pb. 95 percent.

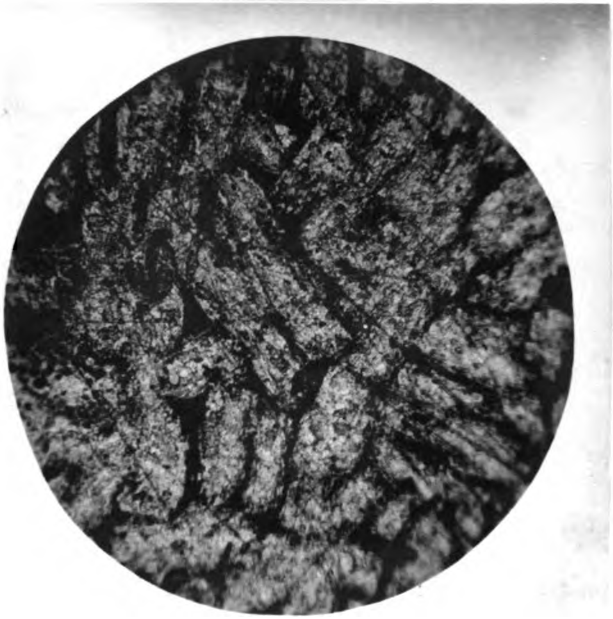
Magnified 110 diameters.



Drawing of Tin, Antimony and Lead Alloy. Sn. 40 percent. Sb. 35 percent. Pb. 25 percent.

Magnified 150 diameters.

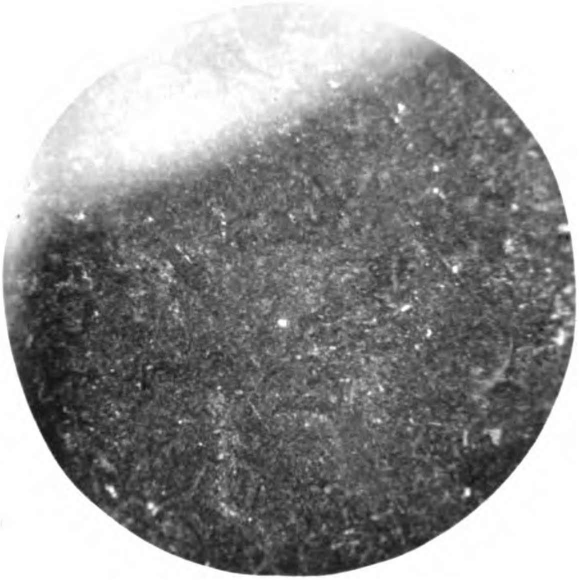
PLATE XIX.



Print 1.

Alloy Tin and Antimony. Sn. $52\frac{1}{2}$, Sb. $47\frac{1}{2}$.

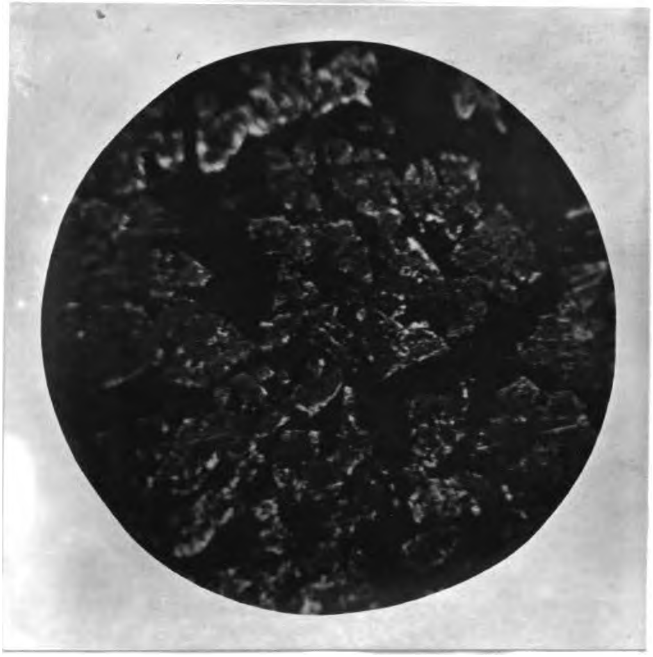
Magnified 130 diameters.



Print 2.

Alloy Lead and Antimony. Pb. 50, Sb. 50.

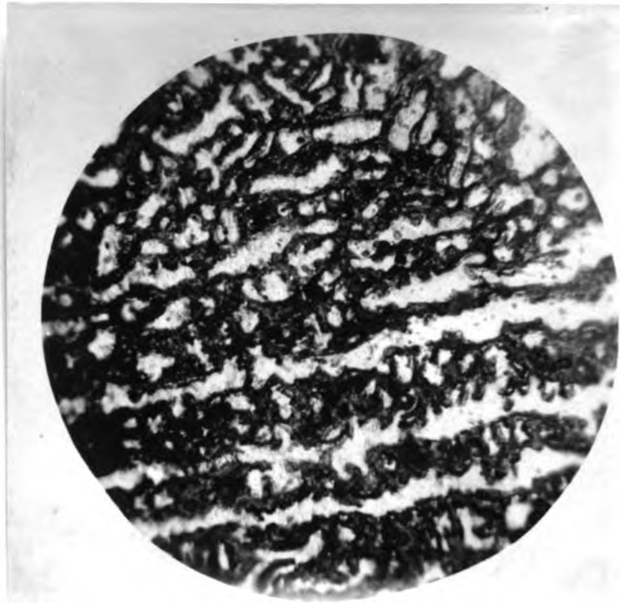
Magnified 130 diameters.



Print 3.

Alloy Lead and Antimony. Pb. 60, Sb. 40.

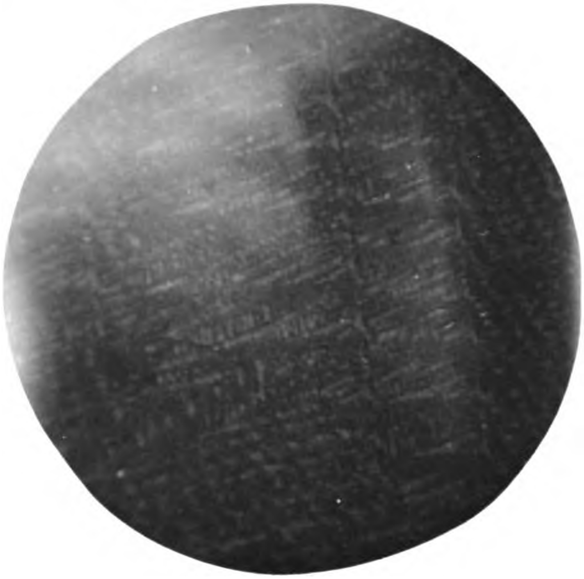
Magnified 130 diameters.



Print 4.

Alloy Lead and Tin. Pb. 10, Sn. 90.

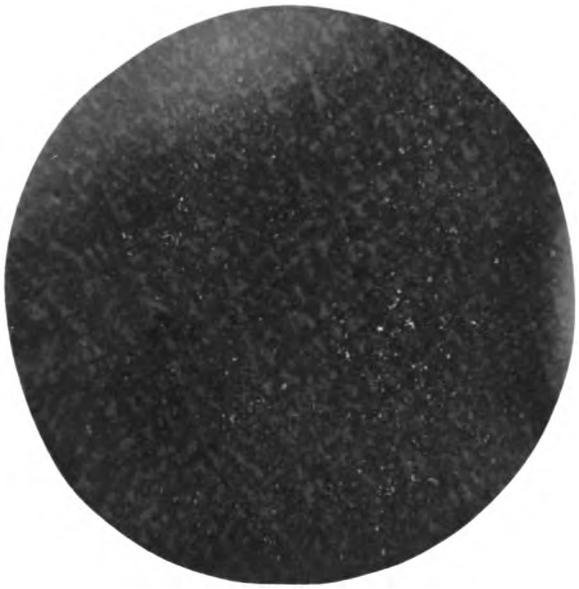
Magnified 130 diameters.



Print 5.

Alloy Lead and Tin. Pb. 30, Sn. 70.

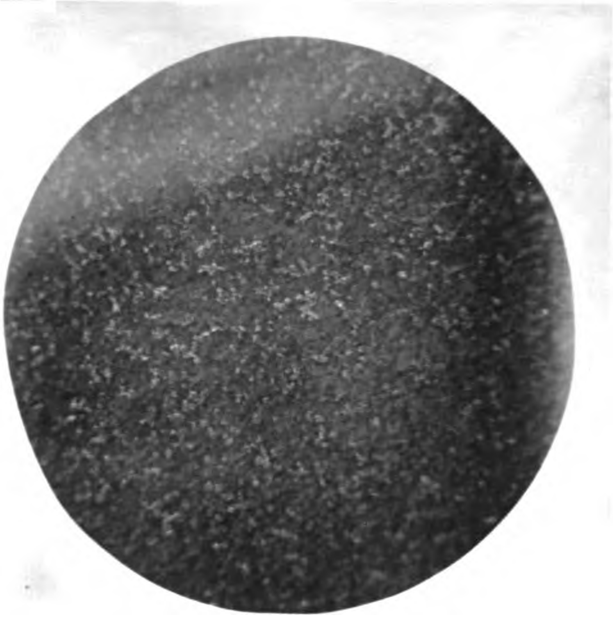
Magnified 130 diameters.



Print 6.

Alloy Lead and Tin. Pb. 40, Sn. 60.

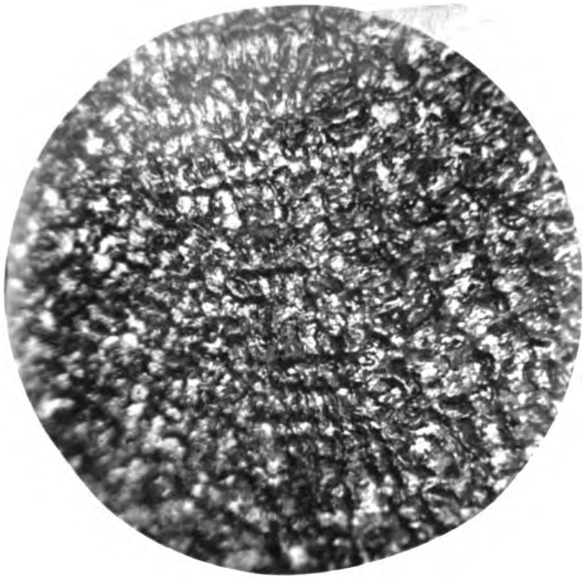
Magnified 130 diameters.



Print 7.

Alloy Lead and Tin. Pb. 50, Sn. 50.

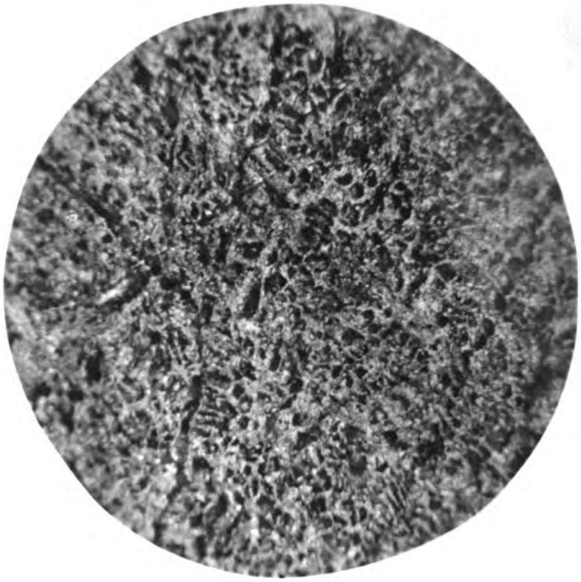
Magnified 130 diameters.



Print 8.

Alloy Zinc and Tin. Zn. 90, Sn. 10.

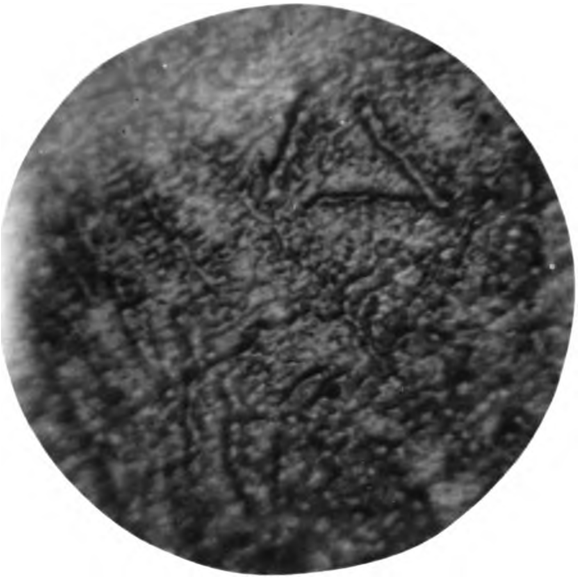
Magnified 130 diameters.



Print 9.

Alloy Zinc and Tin. Zn. 70, Sn. 30.

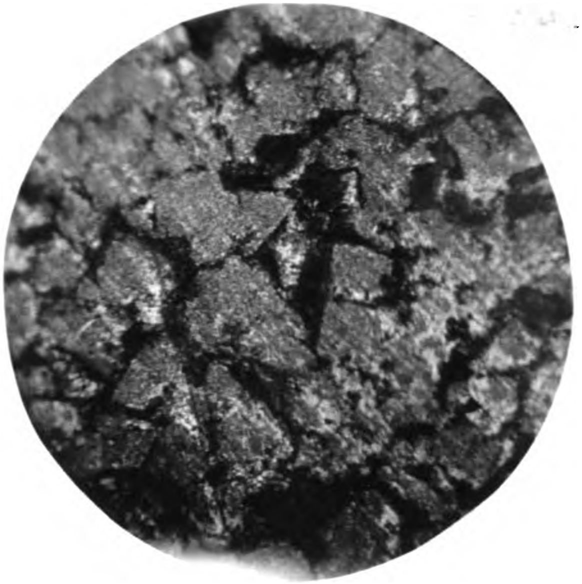
Magnified 130 diameters.



Print 10.

Alloy Zinc and Tin. Zn. 50, Sn. 50.

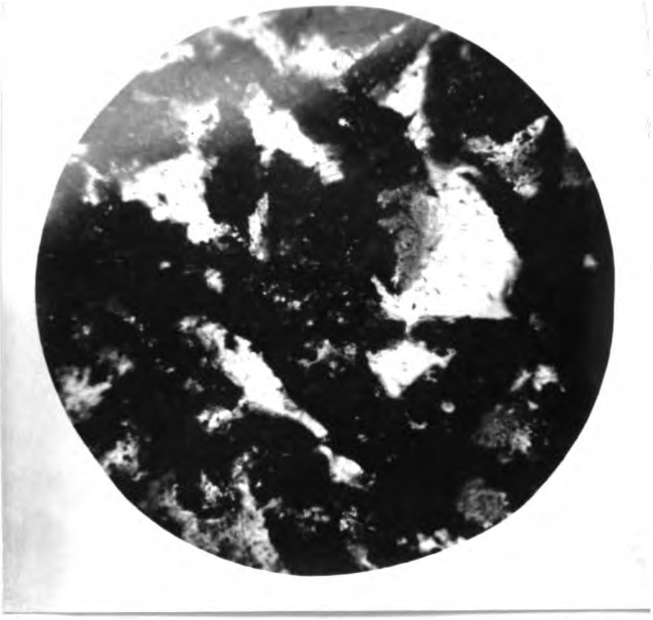
Magnified 130 diameters.



Print 11.

Alloy Tin, Antimony, and Lead. Sn. 40, Sb. 35, Pb. 25.

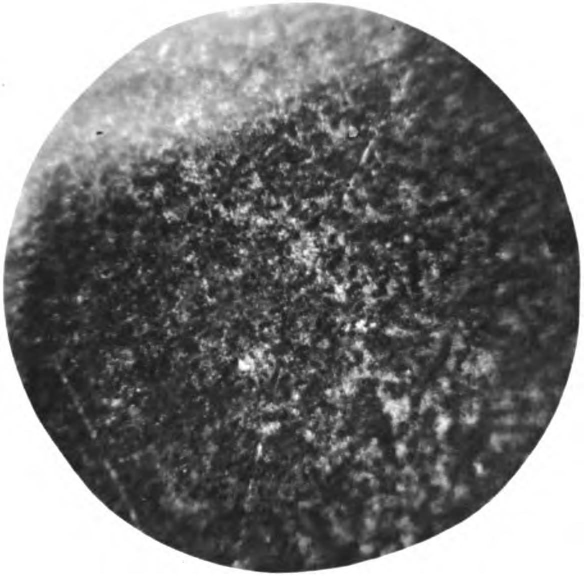
Magnified 130 diameters.



Print 12.

Alloy Antimony, Aluminum, and Lead. Sb. 40, Al. 45, Pb. 15.

Magnified 130 diameters.

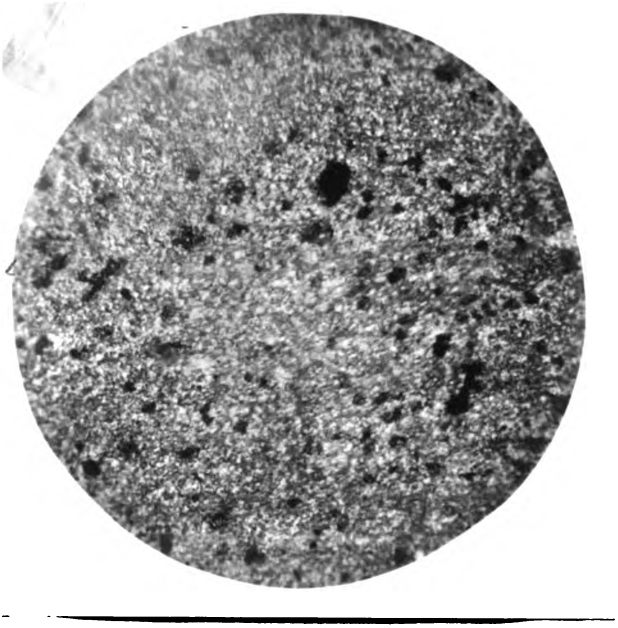


Print 13.

Alloy lead, Zinc, and Antimony. Pb. 80, Zn. 10, Sb. 10.

Magnified 130 diameters.

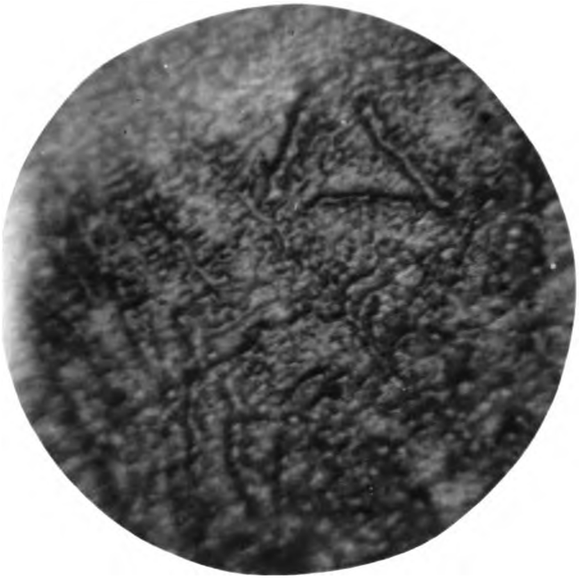
PLATE XXXII.



Print 14.

Alloy Zinc and Lead.   Zn. 90, Pb. 10.

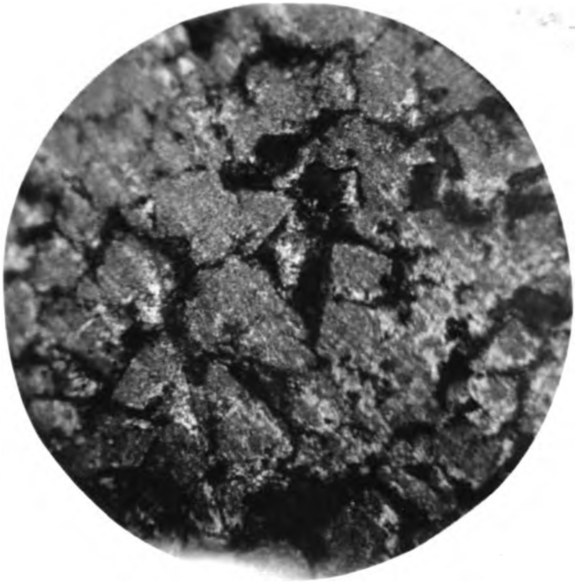
Magnified 130 diameters.



Print 10.

Alloy Zinc and Tin. Zn. 50, Sn. 50.

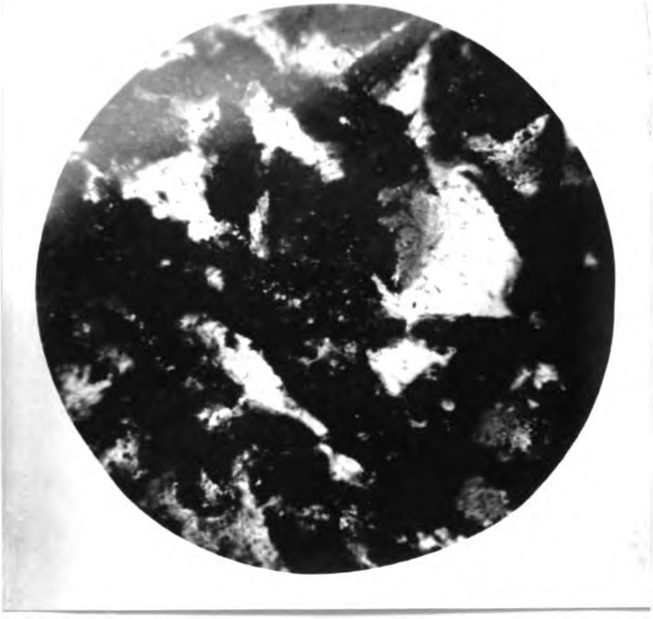
Magnified 130 diameters.



Print 11.

Alloy Tin, Antimony, and Lead. Sn. 40, Sb. 35, Pb. 25.

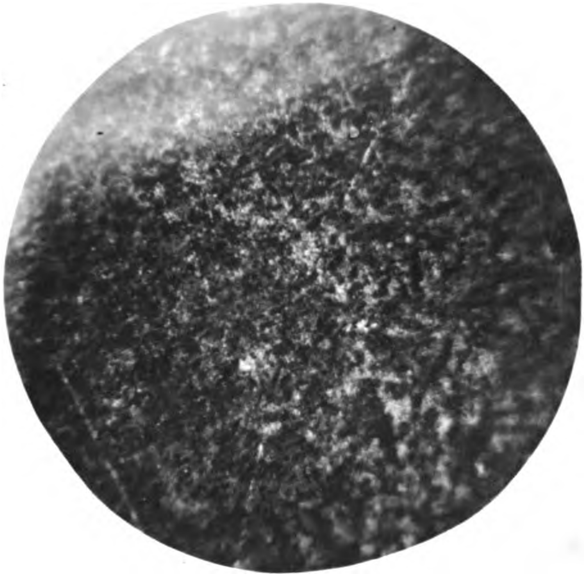
Magnified 130 diameters.



Print 12.

Alloy Antimony, Alumimum, and Lead. Sb. 40, Al. 45, Pb. 15.

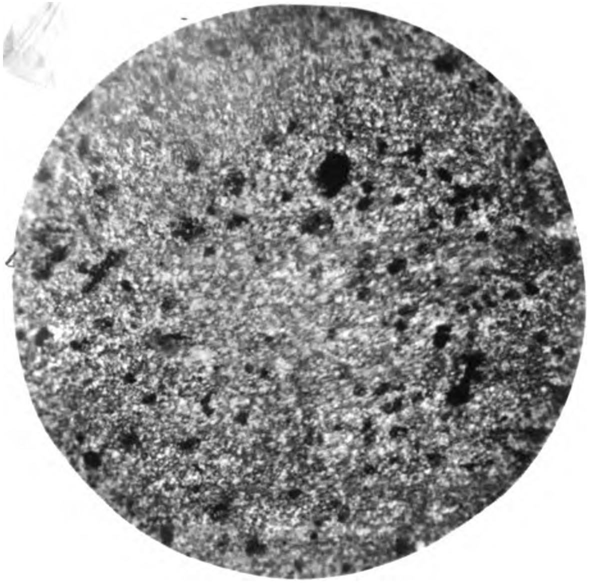
Magnified 130 diameters.



Print 13.

Alloy lead, Zinc, and Antimony. Pb. 80, Zn. 10, Sb. 10.

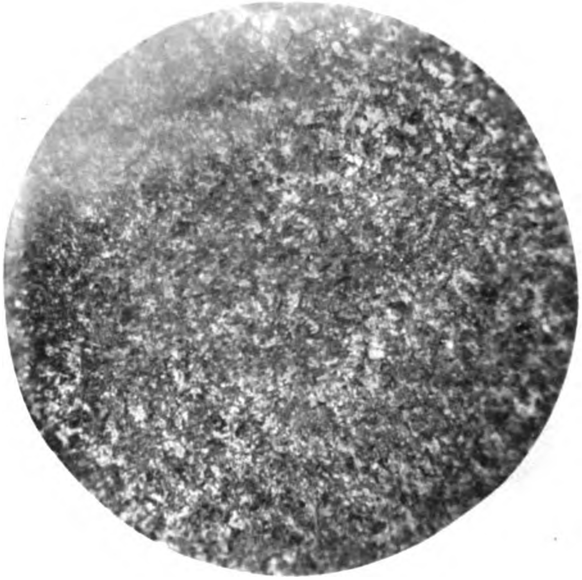
Magnified 130 diameters.



Print 14.

Alloy Zinc and Lead. Zn. 90, Pb. 10.

Magnified 130 diameters.



Print 15.

Alloy Babbit metal. Composition unknown.

Magnified 130 diameters.

APPROVED

. . A. W. Richter . . .

Asst. Professor of Experimental Engineerin

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